ARMORED MEDICAL RESEARCH LABORATORY
Fort Knox, Kentucky

Project No. 20-4
727-2 SPMEA

24 May 1944

1. PROJECT NO. 20 - Studies of Cold Weather Clothing. Sub-Project No. 20-4 - Immobilized Air (OQMG Test Number 57-IV).

a. Authority - Second Indorsement Commanding General, Army Ground Forces, 450 (21 Jan 44) GNRQT 11/39428.

b. Purpose - To determine the amount of thermal insulation lost by convection between layers of two adjacent fabrics, and within the fabrics themselves.

2. DISCUSSION -

a. The maximum insulation attainable within clothing of given thickness is obtained by a layer of immobilized air. Although this is impossible of complete attainment in any garment, efforts to this end have been made in the design of cold weather clothing in that as large a quantity of air as possible is trapped between the layers of cloth comprising an outfit of issue. Convection within the garments cannot be entirely eliminated as there usually exists a marked temperature differential from inside out. One possible way to improve thermal insulation is to provide intimate contact between the surfaces of two adjacent fabrics by intermingling of fibres, thus trapping practically dead air in the interspaces. This will decrease heat losses arising from internal convection.

b. It has been suggested that napping of both adjacent surfaces can bring about such a trapping of air. Outer garments have been made from wind-resistant sateen cloth napped on the inner surface. The 50/50 alpaca-mohair pile garments, trousers and parka, of the arctic zone issue have also been modified by pulling approximately forty (40) per cent of the fibres through the back of the fabric. This results in napping of these adjacent surfaces of these garments. The modified combination of clothing has been compared in protective value to the standard arctic zone issue.

3. CONCLUSIONS -

a. No increase in insulation was observed from the napping of either the sateen windproof outer garments or the pile garments.

b. Both the standard issue and the modified napped issue have the same inherent insulation of approximately five (5) clo.

c. Subjectively, no differences in comfort sensations were reported with the wearing of these two issues or combinations thereof.

4. RECOMMENDATIONS -

a. That the proposed method of napping of garments not be considered a satisfactory means for enhancing the insulating value of clothing.

Submitted:
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3 Incls.
#1 - Appendix
#2 - Tables I, II & III
#3 - Figs. 1 thru 5; 1 and 2 missing (unobtainable)

APPENDIX

I. EXPERIMENTAL PROCEDURES

Control Clothing worn by subjects in this test:

Drawers, Wool, 50/50
Undershirt, Wool, 50/50
Shirt, Flannel, O.D.
Trousers, Field, Pile
Trousers, Field, Cotton, O.D., Sateen, 9 oz.
Parka, Field, Cotton, O.D., Sateen, 9 oz.
Parka, Pile
Shoe, Arctic, Felt
Socks, Wool, ski (2 pairs)
Socks, Wool, cushion (1 pair)
Mittens, Insert, Trigger Finger M-1943
Mittens, Shell, Trigger Finger M-1943
Mufflers, Wool
Wristlets, Knit

Experimental Clothing

The experimental items listed below were identical in style with the standard Arctic Issue but were modified by having one surface well napped and raised.

(1) Parka, Field, Pile 50/50 Alpaca, napped
Trouser, Field, Pile 50/50 Alpaca, napped

The outer napping on the above garments was accomplished by pulling approximately forty (40) per cent of the fibers through the back of the fabric (Fig. 2).

(2) Parka, Field, Cotton, Napped 9 oz. Sateen
Trousers, Field, Cotton, Napped 9 oz. Sateen

The napping on the above was performed on the inside of the cotton outer shell (Figure 1). The two innermost layers of the arctic zone issue remained unaltered during the test. Observations were made at ambient temperatures of 0°, -10°, and -33°F with wind velocities of either zero (0) or five (5.0) miles per hour. The majority of tests were conducted at -10°F and unless otherwise stated the data obtained at this temperature will be used throughout this discussion. On six of the eight subjects measurements of the insulative value of the combinations worn were made. The procedure for obtaining body and skin temperatures and metabolism are similar to those used in the other studies* of this series. Data obtained during tests on a copper cylinder clothed in the experimental fabrics is being presented later.

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* Project No. 20-2 - Insulation provided by Windbreaks.

Incl #1

The requirement for two napped layers in apposition with each other to trap a layer of air may not be necessary. The use of a single napped layer of fabric might give as efficient an immobilization of air as would two layers. Therefore tests were conducted on the following modifications of the arctic assembly in order to provide information on this point.

a. the napped sateen outers and standard 1/2 inch pile,

b. the standard sateen outers and napped pile.

II. RESULTS

Subjective Data

The most constant and precisely reportable of the sensory responses to cold are the awareness of the onset of pain in the fingers or toes (a measure of comfort in the extremities) and awareness of the onset of shivering (a measure of general body comfort). Since in some instances men have stated that they shivered only because their extremities became unbearably cold, the relationship between these two comfort criteria is not clear. However, until further investigation clarifies this interrelationship the use of these criteria will serve the purposes of this report.

In Figures 3 and 4 are presented data obtained on the subjective responses of the subjects dressed in the various experimental combinations. The responses obtained when the control garments (sateen and ½ inch pile) were worn are presented for the subjects' best and worst days in these garments. No differences are evident in the subjective responses of a subject dressed in the various combinations. The specially napped clothing did not increase the tolerance time before the subject reached an uncomfortable state in either his extremities or body.

Objective Data

In our initial experiments with the napped garments, outers and pile, it appeared that considerable benefit was being gained from these garments. The mean skin temperatures of the first two subjects tested at zero (0) wind velocity were higher than the temperatures found when the unnapped garments were being worn. This was not borne out by subsequent observations on other subjects. No changes were found in four subjects, while in two others the mean skin temperatures were in favor of the regular issue. In Figure 5 these two types of response of the mean skin temperature are shown. When the subjects were exposed to a wind velocity of five (5.0) miles per hour, no differences were observed between the two combinations studied.

Before presenting data on the insulative value of the combinations, it may be well to point out that no combination improved either the comfort impression or the actual rate of fall in the temperature of the extremities. It is again emphasized that the major weakness in arctic clothing lies in the insufficient protection of the extremities while providing torso protection that is almost adequate at the temperatures employed in this study.

Chart #1

The loss of body weight by an individual and the weight gain of his clothing was of the same order of magnitude with both combinations (Table III). The added napping of fabrics did not impose a barrier to water loss. (For additional information on the behavior of the napped fabrics during work, see Project 20-1 - The Effect of Closures on Thermal Protection.)

No significant differences were observed in the predicted equilibrium level of mean skin temperature, O_s, with the wearing of one or the other combination at wind velocities of either zero (0) or five (5) miles per hour as shown below.

PREDICTED EQUILIBRIUM MEAN SKIN TEMPERATURE

Wind Velocity	Sateen Outers Regular Pile	Napped Outers Napped Pile	Sateen Outers Napped Pile	Napped Outers Regular Pile
0	49.1	49.4	48.4	48.4
5	48.4	49.1	48.4	48.4

The same variability previously reported for k, the cooling constant, was found to be present in this study. No relationship could be found between the value of k and the clothing combination being worn.

In tables I and II data on Clo values are presented. It is shown (Table I) that at zero (0) mph, there is no difference between the napped and unnapped garments when sufficient numbers of subjects are studied to eliminate individual differences in response. The average Clo value at a wind velocity of five (5) mph did not differ significantly from the still air value. The differences observed between the Clo values at zero and a five mph did not differ by more than six (6) per cent. In table II are shown the data on the only individual in the series whose responses differed greatly from those observed for the other subjects. His data would lead one to make entirely different conclusions from the above data on a number of subjects; there is no doubt, that for Gr. the napped combination is not as efficient in providing insulation as the standard arctic assembly. This data is also of interest as it illustrates the great variability in hourly Clo values calculated by the standard procedure. There is better agreement when Clo values for those combinations calculated from the predicted equilibrium temperature, O_s, and the metabolic heat production for the third hour are compared but the differences still indicate that thermal protection is not improved by wearing the napped garments.

Studies on the other combinations mentioned with the subjects wearing a single layer of the napped fabric, either pile or sateen, failed to demonstrate any improvement in thermal insulation. Clo values calculated from O_s with subjects exposed to an air movement of five (5) miles per hour were 4.8 for the sateen and napped pile combination and 4.5 for the napped sateen and standard 1/2 inch pile. Subjective sensations were not appreciably different when any of the combinations were worn.

Chel#1

III. SUMMARY OF RESULTS

No differences were apparent between unmapped and mapped garments from the standpoint of any of the indices employed in these tests. The failure to detect differences was undoubtedly due to the influence of other avenues of large heat loss not affected by the modifications under consideration. The most important problem in improvement of arctic clothing, viz. increasing extremity protection, is still unsolved.

Encl #1

TABLE I

Average Clo Values from O_2 for Six Subjects
Exposed to Environmental Temperatures of -25.6°C

	0 M.P.H.		5.0 M.P.H.	
	Mean	Range	Mean	Range
Sateen Outers (9 oz) and Pile, ½ inch	4.9	3.9-5.3	4.6	4.1-5.2
Sateen Outers (9 oz) napped and Pile, ½ inch napped	5.2	4.4-6.9	4.6	4.0-5.3

Chart #2

TABLE II

Clo Values (Calculated by Standard Method and From O_c on Subject Gr.) Exposed to environmental Temperature of -23°C

CLOTHING COMBINATION	WIND VELOCITY M.P.H.	STANDARD				Clo by O_c
		1st hour	2nd hour	3rd hour	Last 2 hours	
Sateen (9 oz.) Outers	0	4.8	4.1	4.3	4.2	4.9
and	0	3.4	4.4	5.9	5.15	4.7
Pile, ½ inch	5	3.6	4.2	4.4	4.3	4.2
Sateen (9 oz.) Outers	0	3.7	3.7	3.5	3.6	4.4
napped and Pile, ½ inch, napped	5	2.6	3.2	3.1	3.2	4.0

check #2

TABLE XII

WEIGHT CHANGES IN SUBJECT AND CLOTHING
FOLLOWING THREE TO FIVE HOURS OF
QUIET SITTING AT -18° to -27°C

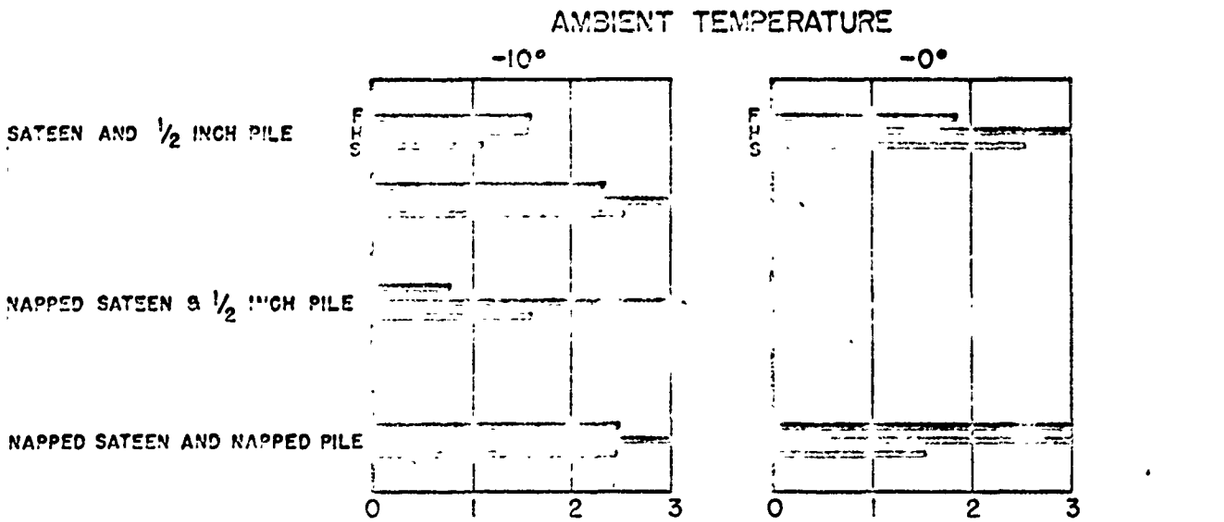
Wind Velocity MPH	Change in Weight of Subject & Clothing Gm/Hr			
	Sateen 9 Oz.		Sateen & Wetted Pile	
	Subject	Clothes*	Subject	Clothes*
0	-57	+43	-56	+24
0	-63	+45	-65	+40
0	-65	+29		
5	-58	+47	-61	+52
10	-76	+76		
10	-66	+52		

* Clothes were dried at 80°C prior to use.

Chart #2

FIG. 4

SUBJECTIVE REACTIONS OF A SUBJECT AT ZERO WIND VELOCITY



- KEY -

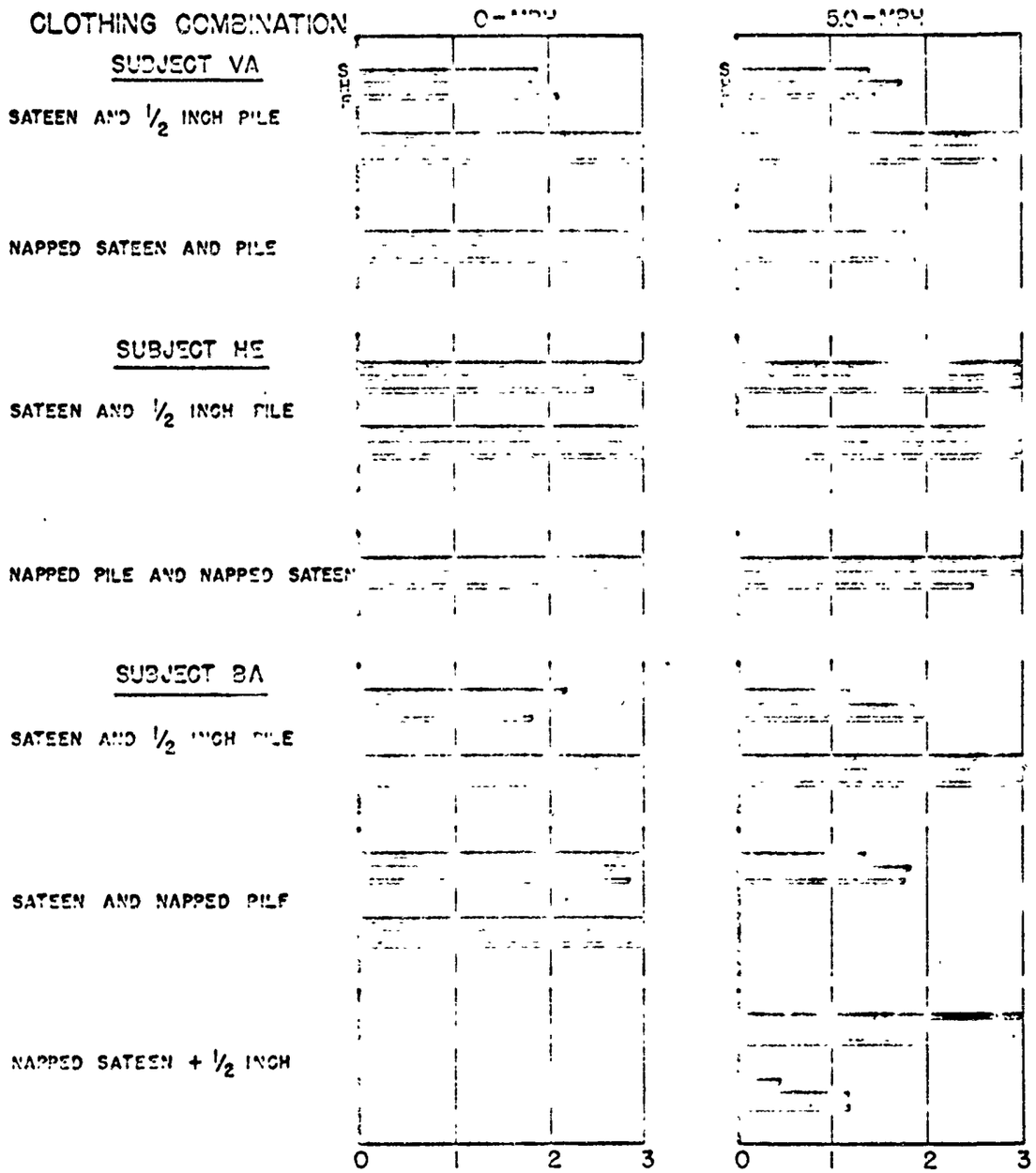
F = ONSET OF PAIN IN FEET
H = ONSET OF PAIN IN HANDS
S = ONSET OF SHIVERING

Incl #3

FIG. 4

FIG. 3

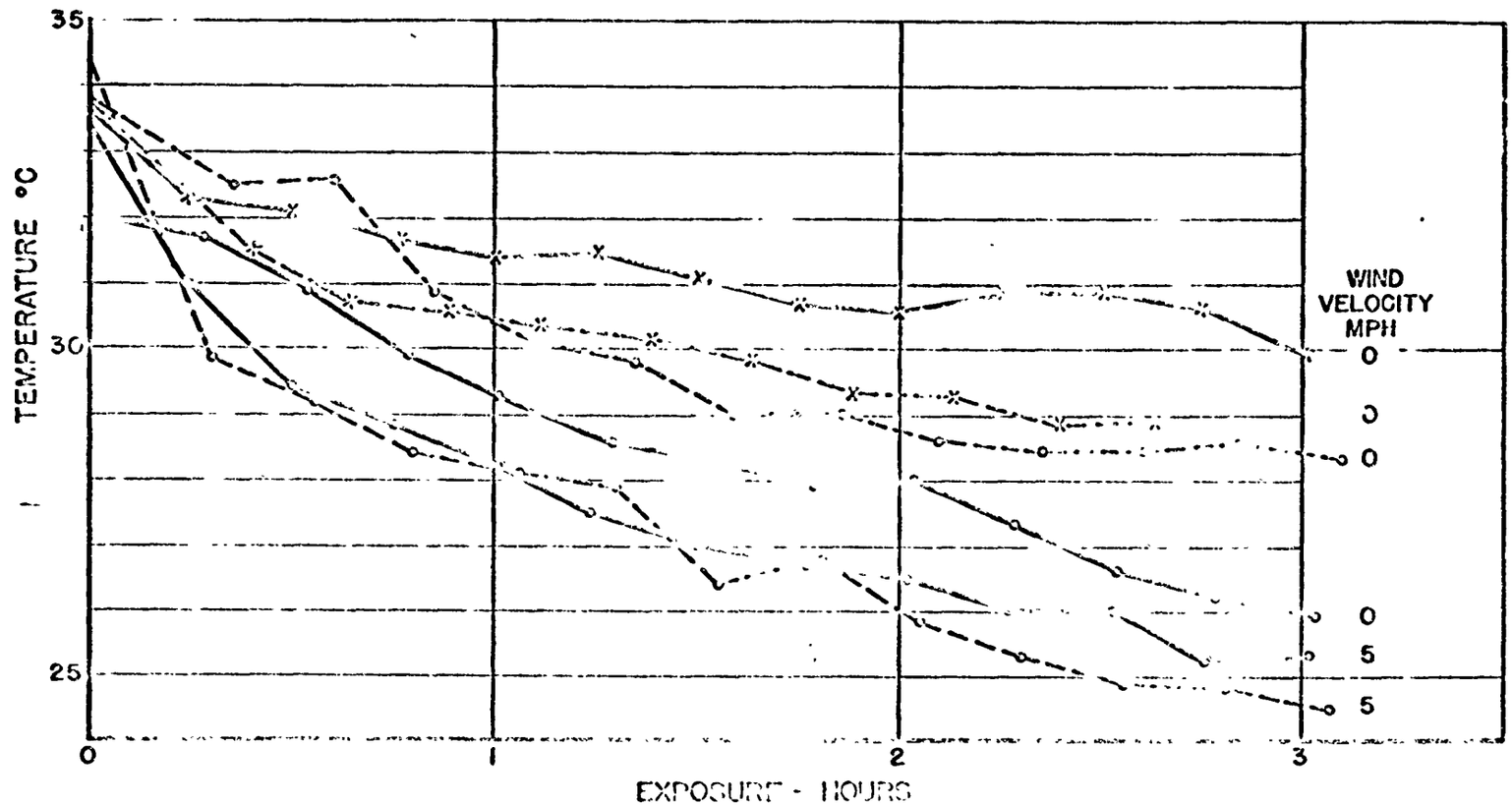
SUBJECTIVE REACTIONS OF MEN EXPOSED TO
-10° F AND WIND VELOCITIES OF 0 AND 5 MPH



Incl #3

FIG. 3

MEAN SKIN TEMPERATURES OF MEN WEARING NAPPED AND UNNAPPED GARMENTS T° = -23.3°C (-10° F) WIND VELOCITIES 0 OR 5 MPH



LEGEND

EXPERIMENTAL, NAPPED ADJACENT SURFACES
REGULAR ARTIC ISSUE (CONTROL)
X SUBJECT VA
o SUBJECT H

FIG. 5